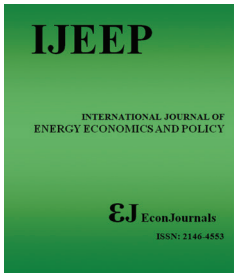

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Integrating Environmentally Friendly Management of Water Resources toward Ecological and Socio-Economic Sustainability

Fajriani Ananda[1,2]*, Nofrizal[3,4], Dessy Yoswaty[3,4], Lena Farida[2], Rasoel Hamidy[3]

[1]Student of Doctoral Program in Environmental Science, University of Riau, Pekanbaru, 28293, Indonesia, [2]Lecturer of Faculty of Social Science and Political Science, University of Riau, Pekanbaru, 28293, Indonesia, [3]Lecturer of Doctoral Program in Environmental Science, University of Riau, Pekanbaru, 28293, Indonesia, [4]Faculty of Fisheries and Marine Science, University of Riau, Pekanbaru, 28293, Indonesia. *Email: fajriani.ananda7404@grad.unri.ac.id; fajriani.ananda@lecturer.unri.ac.id

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ABSTRACT

In small-scale reservoir management, ecological factors must be a top priority, because the sustainability of the ecosystem in the reservoir is very important to maintain sustainable water availability. Efforts to maintain water quality, reduce pollution and maintain the balance of the ecosystem in the reservoir must be carried out consistently. In an effort to maintain the sustainability of small-scale reservoir management, collaboration between the government, local communities and other related parties is needed. By prioritizing ecological, social and economic aspects in a balanced way, it is hoped that the management of water resources in small-scale reservoirs can run in a sustainable manner, provide benefits to local communities, and preserve the surrounding environment. The research method used in this study is to use quantitative methods with a total sample of 137 respondents. Data collection techniques used observation and structured interview techniques to collect data on ecological, social and economic factors that affect the sustainability of small-scale reservoirs. The analysis technique used is the SEM statistical test with AMOS program. Based on the results of the research conducted, it can be concluded that the first hypothesis which states the influence of ecological factors on the sustainability of small-scale reservoirs cannot be accepted. Then the second and third hypotheses show that social and economic factors together have a significant influence on the sustainability of small-scale reservoirs. This shows that in the management of water resources in small-scale reservoirs, not only ecological factors need to be considered, but also social and economic factors.

Keywords: Ecology, Environmental Management, Socio-economic Attributes, Water Resources, Sustainability
JEL Classifications: D24, F62, L11, O13

1. INTRODUCTION

Sustainability of small-scale reservoirs is an important water resource for local communities, especially in areas experiencing drought. Small-scale reservoirs are usually small ponds or reservoirs made by utilizing river flow or rainwater, and are used to store water that can be used for daily purposes such as agricultural irrigation, livestock irrigation, and household needs (Rockstrom, 2000). In addition, small-scale reservoirs can also help reduce the risk of flooding and maintain good water quality for the needs of the community and the surrounding environment. In areas experiencing drought or lack of a stable water supply, small-scale reservoirs can help relieve pressure on the main water supply and provide a more stable water resource for local communities (Laraus, 2004; Kumar, 1999). In addition, the construction of small-scale reservoirs can also help improve food security and local people's welfare by enabling more stable and sustainable agricultural production.

However, management of water resources in small-scale reservoirs often faces challenges in maintaining sustainable water availability. Especially with climate change and increasing demand for water. Climate change, such as increasingly erratic rainfall patterns and higher rainfall intensity, can result in an increase in the flow of

water in the rainy season and a decrease in the flow of water in the dry season. This can affect water availability in small-scale reservoirs (Mulholland et al., 1997). In addition, the increasing need for water, both for agricultural, industrial, and community needs, can also reduce the availability of water in small-scale reservoirs (Abbaspour et al., 2009). To overcome this challenge, integrated and sustainable management of water resources is required. This management includes planning for proper water use, efficient irrigation management, use of environmentally friendly agricultural technologies, and development of wastewater treatment systems. In addition, collaboration between the government, the community and the private sector is also needed in the management of water resources in small-scale reservoirs. Therefore, maintaining the sustainability of small-scale reservoirs is very important to support the survival and economic activities of local communities, as well as maintaining the balance of the ecosystem around the area (Bahri, 1999; Qadir and Oster, 2004).

Ecological factors greatly affect the sustainability of small-scale reservoirs. Reservoirs that are built in areas that have infertile soil or experience high erosion can affect the water quality and quantity of water available in the reservoir. In addition, a decrease in water quality in the reservoir can also occur due to pollution produced by industrial waste and other human activities. Furthermore, social factors play an important role in influencing the sustainability of small-scale reservoirs. This is because the reservoir is used by the local community for their daily water needs, agriculture, and other activities (Mahzun et al., 2020; Soltani et al., 2021). Therefore, public education and awareness regarding the importance of sustainability of water resources is very important to maintain the sustainability of small-scale reservoirs. In addition, economic factors also play a role in the sustainability of small-scale reservoirs. For example, the cost of managing and maintaining a reservoir can be a problem if not managed properly. In addition, affordable water prices for local communities are also important in maintaining the sustainability of small-scale reservoirs. This can affect the level of water use and income derived from agricultural products and other economic activities (Andrews and Shabani, 2012). This research tries to examine in more depth the influence of ecological, social, and economic factors on the sustainability of small-scale reservoirs, therefore this study aims to identify and analyze these factors and provide recommendations for sustainable management of water resources for reservoirs small scale. This research is expected to contribute to efforts to maintain sustainable water availability in small-scale reservoirs, as well as become a reference for decision-making and policy-making in the management of water resources in the future.

2. LITERATURE REVIEW AND HYPOTHESIS

Environmental sustainability was largely set forth with the ecological concept of sustainability, interdependence and connected with the importance of valuing ecological services (Morelli, 2011). Previous research has examined the concept of sustainability which focuses on environmental sustainability (Goodland, 1995). The concept was then developed to cover social sustainability as the world are facing many challenges on climate change and environmental damage. To obtain the optimal benefit, sustainable development goals (SDGs) was set to increase awareness of policy makers, business sector, community and stakeholders all over the world regarding their responsibility to protect the environment. The SDGs was then perfected with many targets including social and economic aspects to ensure that development was equitable for all. Moreover, ElMassah and Mohieldin (2020) argued that ensuring the priorities of local communities can be used as effective tools to localize the SDGs. This highlighted the importance of social factors in environmental management and sustainable development.

Environmental sustainability and sustainable development were now considered as a fundamental point in determining environment development and eco-efficiency all over the word (Vezzoli and Manzini, 2008). However, although ecology is largely connected with sustainability, recent practices often showed the lack the integration between ecology and socio-economic factors that affect the participation of local communities in sustainable development (Nelson and Shilling, 2018). On the other hand, social development accompanied by increased economic activity has increased environmental pressures and ecological stress (Husted, 2005). This denotes the intertwined relationship between three important factors of ecological sustainability, social sustainability and economic sustainability on the overall environmental sustainability (Sachs et al., 2019; Birendra et al., 2021).

Ferreira et al (2012) stated that ecological along with socio-economic considerations can be practically beneficial for policy decisions in local context. This research was to identify important theoretical gaps regarding the ecological factor, and socio-economic aspects in environmental sustainability in the utilization of small-scale reservoir in Riau, Indonesia. Practically, as previous research demonstrated (Donohue et al., 2016), this research was to increasing awareness of environmental policy makers to frame and develop environmental decision on sustainability matters. This was corroborated by Jiménez-Aceituno et al. (2020) stating that to diversify the livelihood options of local communities dependent on local natural resources is determining in the achievement of the development of sustainability.

In many areas all over the world, the sustainability of small-scale reservoirs is crucial to small scale communities and to maintain water reserves. It has the ability to maintain the availability of water in small-scale reservoirs in the long term, without compromising water quality and the ability of the ecosystem in it to survive and thrive. This sustainability aims to ensure that the management of water resources in small-scale reservoirs can continue and provide long-term benefits for local communities, without compromising the ecological and social balance. Ecological aspects of managing water resources in small-scale reservoirs include maintaining water quality and ecosystem balance, as well as efficient and effective water management (Davis, 2007; Yah et al., 2017). The social aspect includes community participation in decision-making and management of water resources, as well as meeting water needs for local communities in a fair and equitable manner. Meanwhile, the economic aspect includes financially sustainable management of water resources, including budget management, marketing of agricultural products, and financial risk management.

In the management of water resources in small-scale reservoirs, an integrated approach is also needed between the government, the community and the private sector, to achieve greater sustainability goals. This involves the participation of local communities in decision-making and management of water resources, as well as government support in providing infrastructure and regulations that support sustainable management of water resources (Gain et al., 2017). Several factors need to be considered in maintaining the sustainability of small-scale reservoirs, including water quality in term of maintaining the quality of water in small-scale reservoirs is very important to ensure the sustainability of water resources. For this reason, regular monitoring is necessary to ensure that the water in the reservoir remains of good quality. The factor of regulating water use was critical in small-scale reservoirs to help maintain a sustainable water supply. This includes determining reasonable water requirements, using efficient technology, and proper water management.

In the context of community participation to be involved in sustainability, involving communities in the management and use of water resources can help maintain the sustainability of small-scale reservoirs. This includes the provision of appropriate information and active participation in decision-making related to the management of water resources. The participation needs to ensure the economic development. This can be achieved through the development of more efficient technologies and more effective use of water resources. Also, this was supported by supportive policies and regulations to achieve Sustainable and effective policies and regulations can help maintain the sustainability. This includes arranging development permits around the reservoir and imposing high water safety standards.

2.1. Hypothesis

In previous studies that carried out socio-ecological analysis in the management of water resources, many have been carried out. Everard (2019) discussed socio-ecological analysis in the management of water resources in water catchment areas. Douglas et al. (2019), McDonnell (2008) show that ecological, social and economic factors greatly influence the successful management of water resources. This includes water quality, ecosystem conditions, community participation, and proper regulation of water use (Hagemann et al., 2014). Adebayo and Ademiluyi (2019) found the potential of small-scale reservoirs as an alternative source of water for agriculture in sub-Saharan Africa. In this study, the research results show that small-scale reservoirs can provide economic and social benefits for agriculture (Herwehe and Scott, 2018; Acheampong et al., 2018), as well as reduce dependence on limited water sources (Kemeze, 2020; Wisser et al., 2010) and climate change adaptation (Lasage et al., 2015; Chowdhury and Hossain, 2021). There are also empirical evidences regarding the sustainability of small-scale reservoir management from the aspects of ecological factors, such as maintaining water quality and ecosystem conditions (Ruan et al., 2021; Mayor et al., 2017).

Zhang et al. (2020) found the ecological, social, and economic benefits of small-scale reservoirs in China. Dutta et al. (2021) and Uchida et al. (2018) showed that small-scale reservoirs provide ecological benefits in maintaining water quality, reducing soil erosion, and improving ecosystem conditions. Meanwhile, there is also a link between the sustainability and the social benefits of small-scale reservoirs including the provision of water for agricultural needs, domestic needs, and tourism development (Doria et al., 2021; Sivaraman et al., 2019; Paul et al., 2020). Meanwhile, the economic benefits of the sustainability include the development of local industries and fisheries (Paul et al., 2020; Galappaththi et al., 2021). Thus, it can be concluded that ecological, social, and economic factors have a significant influence on the sustainability of small-scale reservoirs. Sustainable water resources management needs to pay attention to these three factors to ensure sustainable water availability in small-scale reservoirs. Therefore, the hypothesis in this study can be proposed as follows (Figure 1):

- Hypothesis 1: Ecological factors have a significant effect on the sustainability of small-scale reservoirs
- Hypothesis 2: Social factors have a significant effect on the sustainability of small-scale reservoirs
- Hypothesis 3: Economic factors have a significant effect on the sustainability of small-scale reservoirs.

3. RESEARCH METHODS

The research method used in this study is to use quantitative methods. This research was conducted on a tourist object made in the integrated reservoir area in Dayun in Siak Regency, Riau, Indonesia (Figure 2). The research was conducted in May 2021. The number of samples was determined using a simple random sampling technique of 117 respondents by involving locals in in Siak Sri Indrapura, Riau Province, Indonesia. Data collection techniques used observation and structured interview techniques to collect data on ecological, social and economic factors that affect the sustainability of small-scale reservoirs. Data was also collected through a questionnaire given to respondents who were directly involved in reservoir management. In this study, the analytical technique used was quantitative analysis, also known as verification analysis using the structural equation modeling (SEM) statistical test. The use of SEM according to Hair et al. (2006) allows the analysis of a series of relationships simultaneously so as to provide statistical efficiency. The independent variables (independent) in this study are ecological, social and economic factors. The dependent variable is the sustainability of small-scale reservoirs. Interpret the results of data analysis to determine the influence of ecological, social and economic factors on the sustainability of small-scale reservoirs.

Figure 1: Conceptual framework

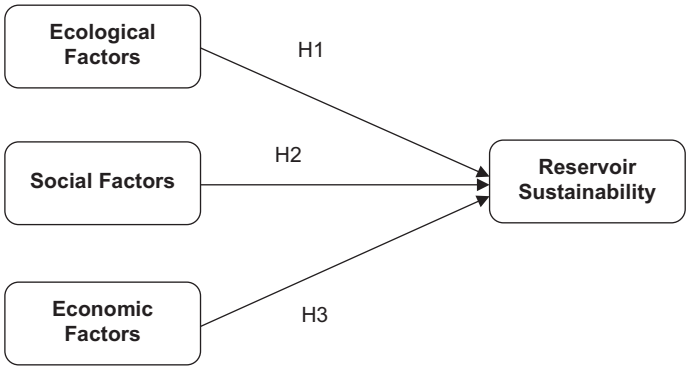
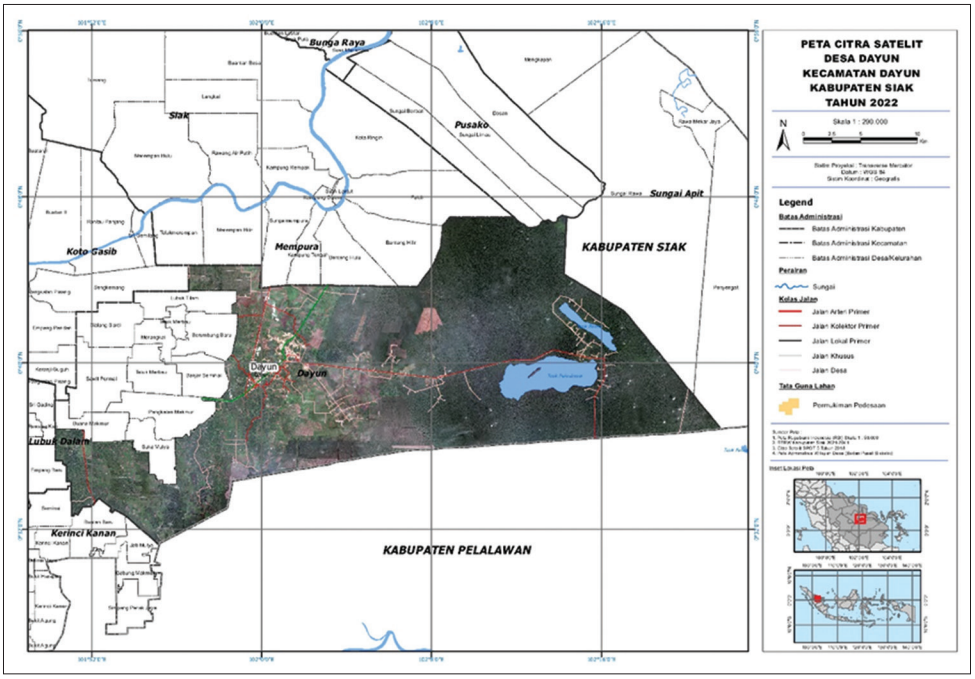


Figure 2: The location of research



4. RESULTS

In testing the reliability of the variables used in this study is to look at the value of the standard loading factor, critical ratio and AVE value. If the standard loading factor value is above 0.6, the critical ratio is more than 0.7 and the AVE value is more than 0.5, then the variables used in this study are reliable. The independent variables in this study are ecological, social and economic factors. Then, the dependent variable is the sustainability of small-scale reservoirs. The results of the reliability test in this study obtained the results presented in Table 1.

The results of the variable reliability test in the table above show that the standard loading factor values obtained from each variable are sufficient for the minimum acceptable limit, which is in the range of 0.613–0.930. Standard loading factor is the value of the correlation coefficient between variables and their latent factors measured in factor analysis. The higher the value of the standard loading factor of a variable, the stronger the relationship between the variable and its latent factors. The critical ratio values of all variables also meet the minimum acceptable limit values, which are in the range of 0.841773–0.901927. Then the AVE value obtained is also above the minimum acceptable value, which is in the range 0.51836–0.650823. From the results of the variable reliability test, it can be concluded that the variables used in this study are reliable and can be used.

The management of small-scale reservoirs analyzed in this study is influenced by ecological, social and economic factors. The results showed that social factors such as community participation in management and environmental awareness also have a significant effect on the sustainability of small-scale reservoirs. Meanwhile, economic factors such as operational and maintenance costs also play an important role in the sustainability of small-scale reservoirs. The results of the SEM analysis using AMOS can be seen in Figure 3 below.

Table 1: Reliability test results

Relationship			Standard loading factor	Critical ratio	AVE value
Ecological factors	<---	ECL1	0.732	0.842859	0.51836
	<---	ECL2	0.714		
	<---	ECL3	0.742		
	<---	ECL4	0.643		
	<---	ECL5	0.763		
Social factors	<---	SEC1	0.795	0.893693	0.627491
	<---	SEC2	0.836		
	<---	SEC3	0.811		
	<---	SEC4	0.733		
	<---	SEC5	0.782		
Economic factors	<---	ECO1	0.613	0.841773	0.518989
	<---	ECO2	0.710		
	<---	ECO3	0.736		
	<---	ECO4	0.862		
	<---	ECO5	0.656		
Reservoir sustainability	<---	RS1	0.821	0.901927	0.650823
	<---	RS2	0.930		
	<---	RS3	0.786		
	<---	RS4	0.643		
	<---	RS5	0.827		

From the results of the SEM analysis in Figure 3, it shows that the Goodness of Fit value obtained is quite good, where the chi-square value is 282,605 where this value can be said to be fit. The probability value obtained is still below the cut-off value, which is <0.05. The RMSEA and CMIN/DF values get values of 0.073 and 1.723, these values can also be said to be fit. Then the NFI, TLI, GFI, AGFI and CFI values obtained values of 0.827, 0.905, 0.826, 0.777, 0.918. This value does not yet exceed the cut-off value, but it is very close so that it can be said to be marginal. In more detail, the results of the goodness of fit test are presented in Table 2.

Furthermore, to determine that the independent variables (ecological, social and economic factors) have a relationship with

Figure 3: Analysis result of structural equation model

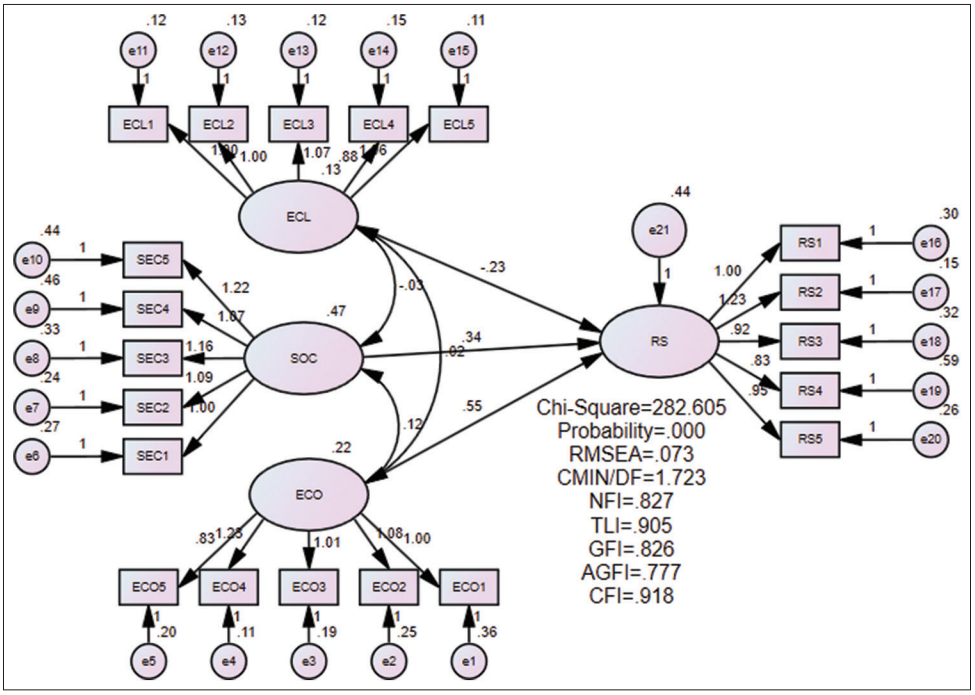


Table 2: Goodness of fit

S. No.	Goodness of fit index	Cut-off value	Result	Information
1.	Chi-Square	Small	282.605	Fit
2.	Probability	>0.05	0.000	Marginal
3.	RMSEA	<0.08	0.073	Fit
4.	CMIN/DF	<2.0	1.723	Fit
5.	NFI	>0.90	0.827	Marginal
6.	TLI	>0.95	0.905	Marginal
7.	GFI	>0.90	0.826	Marginal
8.	AGFI	>0.90	0.777	Marginal
9.	CFI	>0.95	0.918	Marginal

the dependent variable (reservoir sustainability) a significance test is carried out. The results of the significance test in this study are presented in Table 3.

The results of the first hypothesis significance test show that the ecological factor in its effect on reservoir sustainability is less acceptable, because the P-value obtained is > 0.05. Then in the second hypothesis significance test the effect of social factors on reservoir sustainability obtained a P-value of 0.003, meaning that the hypothesis was accepted because the P-value obtained is <0.05. The results of this study are in line with previous research conducted by Mahzun et al. (2020) which states that social factors have a positive and significant influence on reservoir sustainability. The third hypothesis which states that economic factors influence reservoir sustainability also gets a P < 0.05, which is equal to 0.001 and it can be concluded that the third hypothesis in this study is accepted.

The results showed that sustainability of small-scale reservoirs involves managing water resources effectively and efficiently, taking into account ecological, social and economic aspects in a balanced way in order to maintain water availability and sustainably manage it in the future (Davis, 2007; Mahzun et al., 2020). This aims to ensure that the availability of water in the reservoir can be maintained for a long period of time, as well as providing benefits to local communities and the surrounding environment. In small-scale reservoir management, ecological factors must be a top priority, because the sustainability of the ecosystem in the reservoir is very important to maintain sustainable water availability. Efforts to maintain water quality, reduce pollution, and maintain the balance of the ecosystem in the reservoir must be carried out consistently (Van Koppen and Schreiner, 2017). Ecological aspects that affect small-scale reservoir management include water availability, water quality, and the condition of the ecosystem in the reservoir. Small-scale reservoir management must consider these ecological factors so that water availability can be maintained and ecosystem conditions in the reservoir remain balanced.

In addition, social aspects have a significant effect on the sustainability. The success of small-scale reservoir management is highly dependent on the active participation of local communities in decision-making and management of water resources. Local communities can utilize the opportunity to benefit from water resources in reservoirs, as well as be given information about the importance of maintaining the sustainable management of water resources in their area. Social aspects include community participation in the management of water resources, water needs for local communities, and access rights to water resources (Davis, 2007). Therefore, small-scale reservoir management must also pay attention to the needs of local communities and provide opportunities for communities to participate in decision-making and management of water resources in their area.

The results also showed that economic aspects have a significant effect on in small-scale reservoir management. Therefore, the

Table 3: Hypothesis testing

Hypothesis			Estimate	S.E.	C.R.	P-value	Information
Reservoir sustainability	<---	Ecological factors	−0.227	0.189	−1.198	0.231	Not significant
Reservoir sustainability	<---	Social factors	0.34	0.113	2.999	0.003	Significant
Reservoir sustainability	<---	Economic factors	0.555	0.172	3.232	0.001	Significant

management of water resources in the reservoir must consider operational and maintenance costs, as well as potential income from the products produced from the reservoir. Economic aspects include the operational and maintenance costs of the reservoir, the economic value of production results obtained from the reservoir, as well as the potential economic losses that might occur in poorly maintained reservoir (Zhang et al., 2020). Therefore, management of small-scale reservoirs must also take into account economic aspects to ensure that the management of water resources can be financially sustainable (Gannon, 1994).

5. CONCLUSION

Based on the results of the research conducted, it can be concluded that the first hypothesis which states the influence of ecological factors on the sustainability of small-scale reservoirs cannot be accepted. This may be due to several factors, such as a lack of adequate data or measurements for the ecological factors selected in the study, or a lack of understanding of the relationship between ecological factors and water availability in small-scale reservoirs. Then the second and third hypotheses show that social and economic factors together have a significant influence on the sustainability of small-scale reservoirs. This shows that in the management of water resources in small-scale reservoirs, not only ecological factors need to be considered, but also social and economic factors. The importance of social and economic factors in small-scale reservoir management indicates that local community participation and economic activities around the reservoir area can affect the availability of water in the reservoir. Therefore, management of water resources in small-scale reservoirs must consider social and economic aspects in a balanced way to ensure sustainable water availability and benefits for local communities and the surrounding environment.

In an effort to maintain the sustainability of small-scale reservoir management, collaboration between the government, local communities and other related parties is needed. By prioritizing ecological, social and economic aspects in a balanced manner, it is hoped that the management of water resources in small-scale reservoirs can run in a sustainable manner, provide benefits to local communities, and preserve the surrounding environment. Practically, in maintaining the sustainability of small-scale reservoirs, it is necessary to adopt a holistic approach that pays attention to ecological, social and economic factors in a balanced manner. Efforts made include sustainable management of water resources, development of environmentally friendly technologies, social and educational development, as well as supportive economic policies. To maintain sustainable water availability in small-scale reservoirs, it is necessary to pay attention to the factors that affect the sustainability of small-scale reservoirs, namely ecological, social and economic factors.

The implication of these findings is that to achieve optimal sustainability, small-scale reservoir management must consider ecological, social and economic factors together. Management must involve community participation, increase environmental awareness, improve water quality, maintain the existence of riparian vegetation, and pay attention to economic aspects in maintenance and operations. In this case, local governments need to make policies that encourage community participation in small-scale reservoir management, provide education and training to the community regarding the sustainability of water resources, and provide incentives or subsidies for sustainable management. Likewise, the owner or manager of a small-scale reservoir needs to pay attention to water quality, the presence of riparian vegetation and economic aspects in daily management. It is hoped that the findings from this research can contribute to a more sustainable management of small-scale reservoirs and the like.

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